NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM

No. 1173

PRESSURE DISTRIBUTION MEASUREMENTS ON A TURBINE ROTOR BLADE PASSING BEHIND A TURBINE NOZZLE LATTICE

By Hausenblas

Translation

"Druckverteilungsmessungen an einer sich hinter einem Turbinendüsengitter vorbeibewegenden Turbinenlaufschaufel." Berichte der Gittertagung in Braunschweig, Institut für Motorenforschung der Luftfahrtforschungsanstalt Hermann Göring, März 27 und 28, 1944, Br.B. Nr. M325/44g

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As a turbine rotor turns, the blades traverse the wake zones of the nozzle vanes. A periodic fluctuation of the pressure distribution around the circumference of the rotor blade is therefore caused. It was desired to investigate quantitatively this effect. At the same time, the magnitude of the force acting upon one profile of the rotor-blade lattice at various positions of this lattice relative to the nozzle lattice was to be determined.

Figure 1 shows the double-lattice arrangement used for the measurements. The spacing selected for the nozzle lattice was exactly double that of the rotor-blade lattice. The taps for measurement are numbered 1 to 8 on the pressure side and also on the suction surface of the profile; in each series, tap 1 is near the leading edge of the profile and tap 8 is near the trailing edge.

In figure 2 are plotted the curves of the static pressures measured at each of these taps as a function of the position of the rotor-blade lattice relative to the nozzle lattice. The measured pressures minus the static pressure behind the rotor-blade lattice were made dimensionless by dividing by the pressure difference between the total pressure ahead of the double-lattice rig and the static pressure behind the rotor-blade lattice.

In figure 2, that position of the two lattices relative to each other is designated the reference position; at this position the rotor blade provided with the taps, which will be called the test blade, has its leading edge directly downstream of the trailing edge of the nozzle vane profile.

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*"Druckverteilungsmessungen an einer sich hinter einem Turbinendüsengitter vorbeibewegenden Turbinenlaufschaufel." Berichte der Gittertagung in Braunschweig, Institut f. Motorenforschung der Luftfahrtforschungsanstalt Hermann Göring, März 27 u. 28, 1944, Br.B. Nr. M325/44g, pp. 95-100.

The following peculiarities of the curves are especially noteworthy:

1. The portion of the travel of the rotor-blade lattice behind the nozzle lattice that is influenced by the wake zones of the nozzle lattice amounts to almost one-half of the spacing of the nozzle vanes.

2. With the exception of pressure tap 1 on the pressure surface and taps 1 and 2 on the suction surface, the pressure differences operating on the profile within the wake zones are, as was expected, smaller than outside the wake zones.

3. Pressure tap 1 on the pressure surface shows almost constant pressure throughout.

4. Surprisingly, taps 1 and 2 on the suction side of the blade show strong pressure differences precisely in the wake zones, differences which increase especially markedly just when suction-surface test point 1 enters and leaves the wake zone of the nozzle vane.

5. At the borders of the wake zones, fluctuations of the pressure curve occur, as was, of course, to be expected.

Figure 3 shows two examples of curves of pressure distribution over the circumference of the profile, namely plotted against perpendicular distance from the lattice axis. Curve 1 shows a pressure distribution for the case in which the rotor-blade profile is within the nozzle-vane wake zone, whereas curve 2 shows the case in which the rotor blade is outside the wake zone.

The most noteworthy difference is that the pressure minimum on the suction side near the leading edge is substantially less marked in the free flow than in the wake zone.

If the area enclosed by such a pressure-distribution curve as shown in figure 3 is measured with a planimeter and divided by the axial dimension of the lattice a rotational force coefficient is obtained. This computation was made for each position of the rotor-blade lattice relative to the nozzle-blade lattice (more than 40 series of measurements were made) and the curve in figure 4 was thereby obtained. Here can be clearly seen the drop in the rotational force operating on the rotor blade within the wake zone. Another point about this curve that is certainly noteworthy is the relatively high peak reached by the value of the rotational force coefficient on the entrance of the pressure side of the rotor blade into the wake zone of the nozzle blade.

The next step in the investigation was the harmonic analysis of the curve in figure 4. The result is shown in figure 5. It may be seen that only the basic frequency and the first harmonic exhibit substantial amplitudes, whereas all other harmonics have smaller amplitudes. The fact that the odd-numbered harmonics in each case are greater than the even-numbered ones is unimportant; the inaccuracies of the measurements are largely involved herein.

As these investigations prove, the periodic fluctuation of the rotational force certainly cannot be omitted from consideration as a cause of vibration in the rotor blades. It should be noted that the amplitude of the first harmonic amounts to about 24 percent of the mean value of the peripheral force. It is certainly impossible to transfer without any alteration the results presented here, which were obtained at low velocities of rotor-blade travel, to the actual turbine with its high peripheral velocities, for, as is well known, circulation changes require a certain length of time for development. Nevertheless, it may be assumed that even in that case the first harmonic must be considered as an important cause of rotor-blade vibrations.

DISCUSSION

It was pointed out that in the rapid passage of the rotor blades behind the stator blades in a turbomachine the time is too short for the boundary layers to respond fully to the periodic changes in the incident flow conditions thus caused. For this reason, it is to be expected that the results of the experiments presented by Hausenblas could not be applied without change to the relations in a running turbine. Hausenblas observed in this connection that his experiments were primarily intended as a foundation for the calculation of blade vibration.

Translation by Edward S. Shafer,
National Advisory Committee
for Aeronautics.

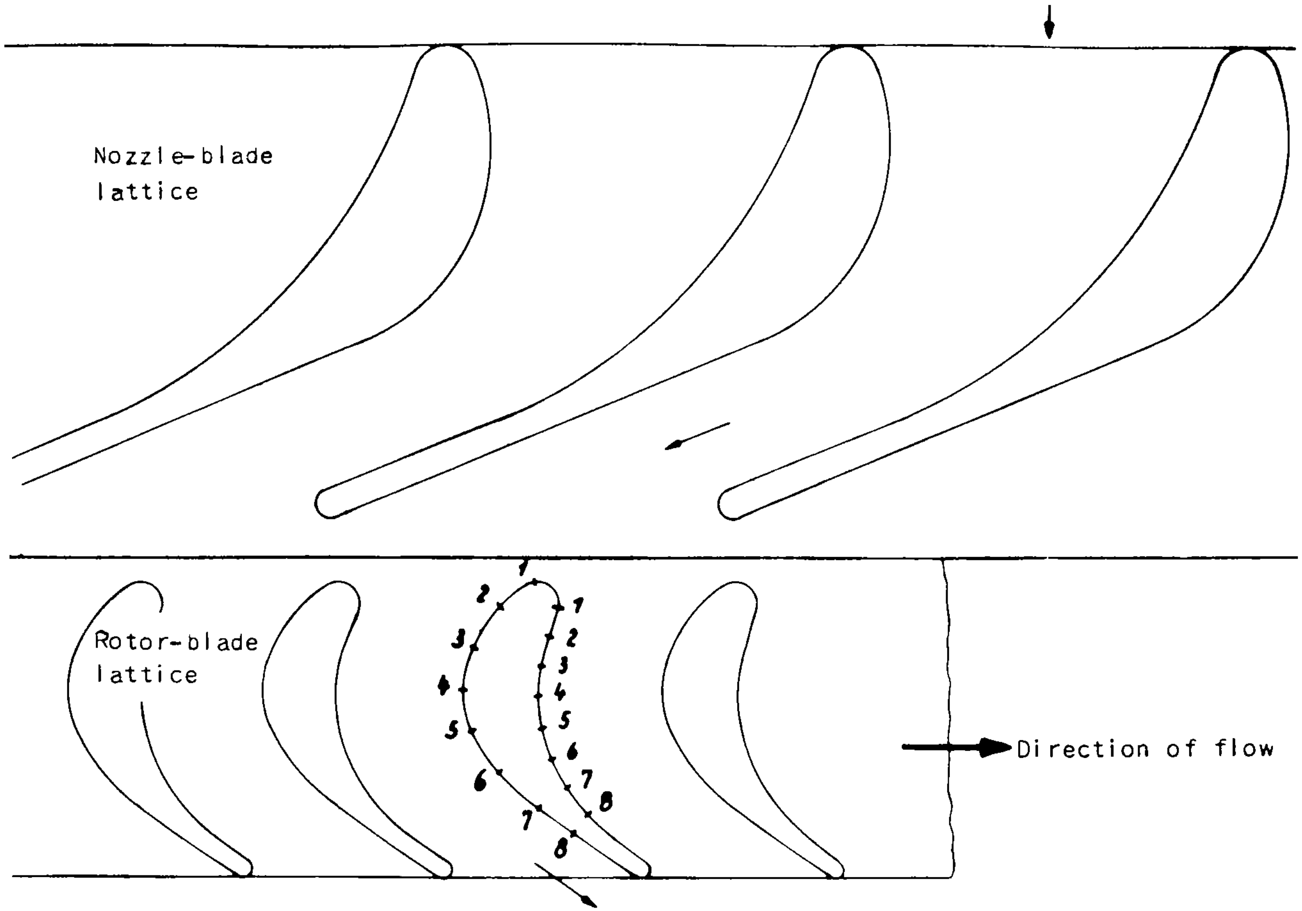


Figure 1. - Double lattice arrangement DÜ-B 2.

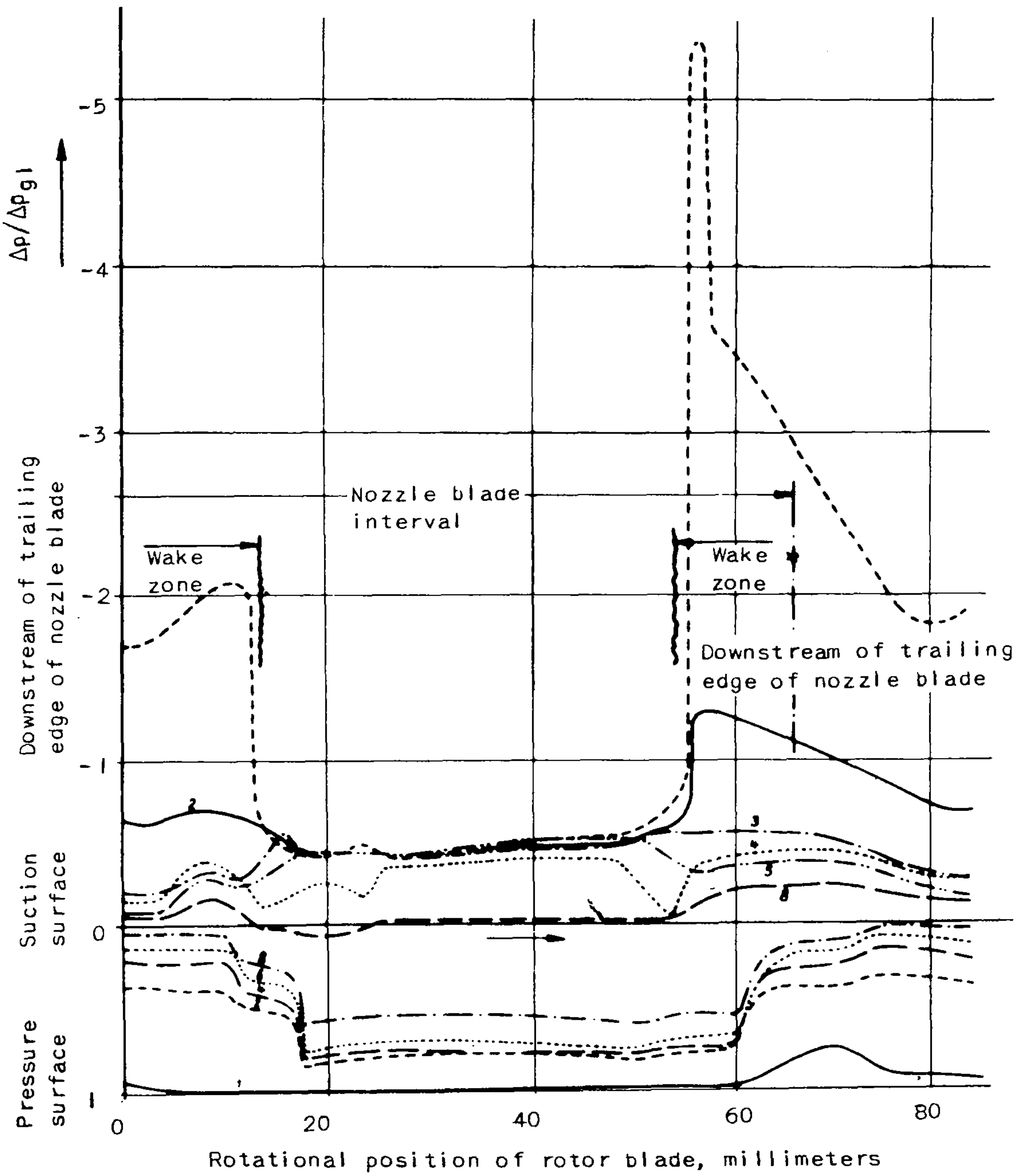
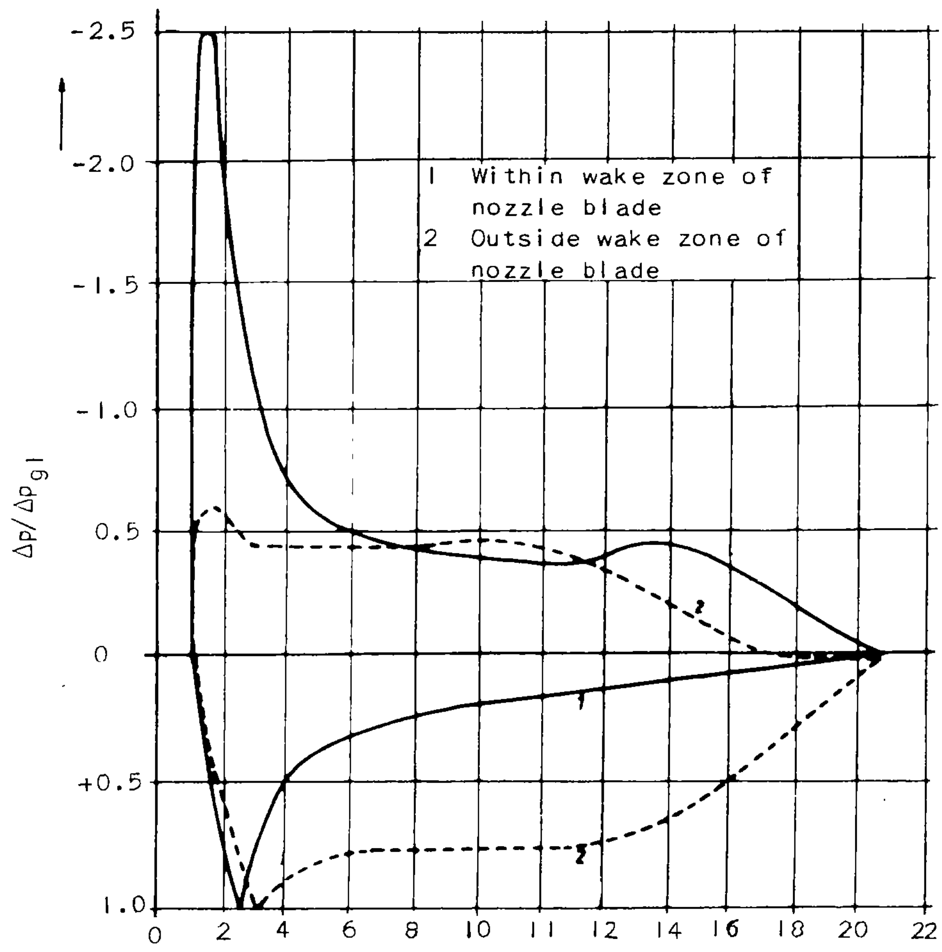


Figure 2. - Pressures at individual measuring taps (double lattice investigation).



x, millimeters

Figure 3. - Pressure distribution around circumference of profile (double lattice investigation).

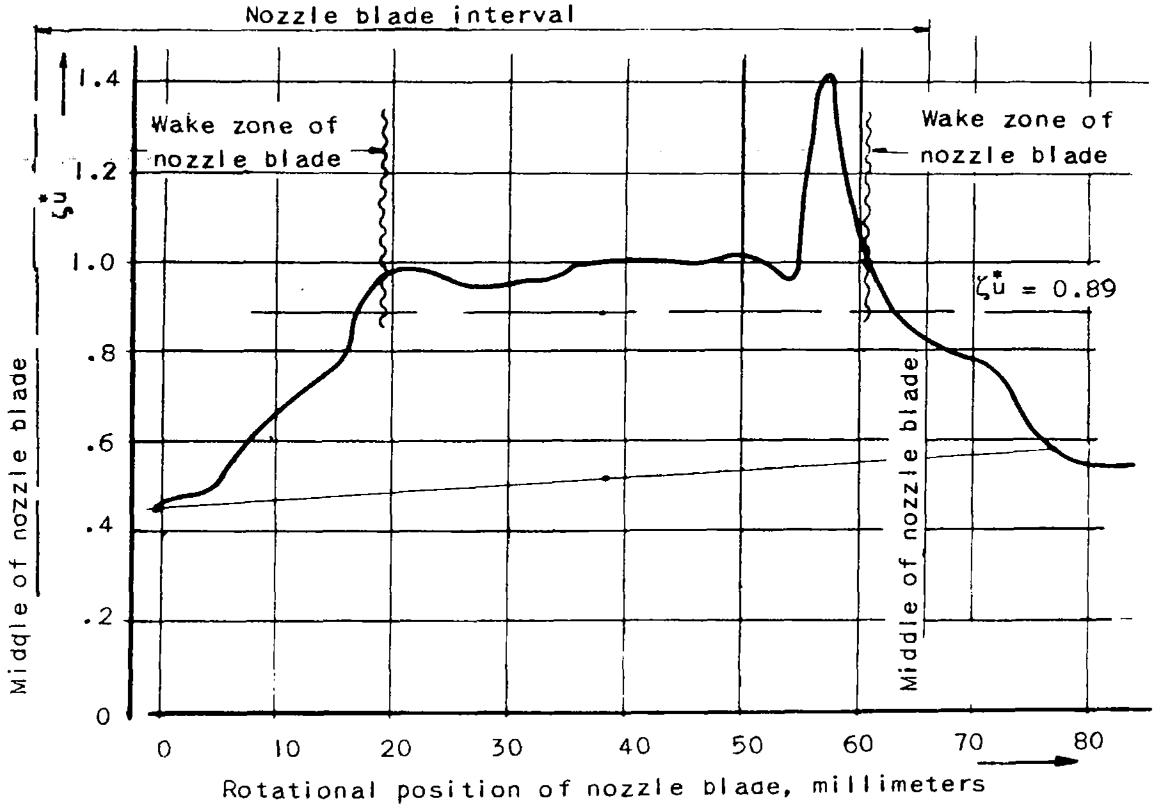


Figure 4. - Rotational force coefficient (double lattice investigation).

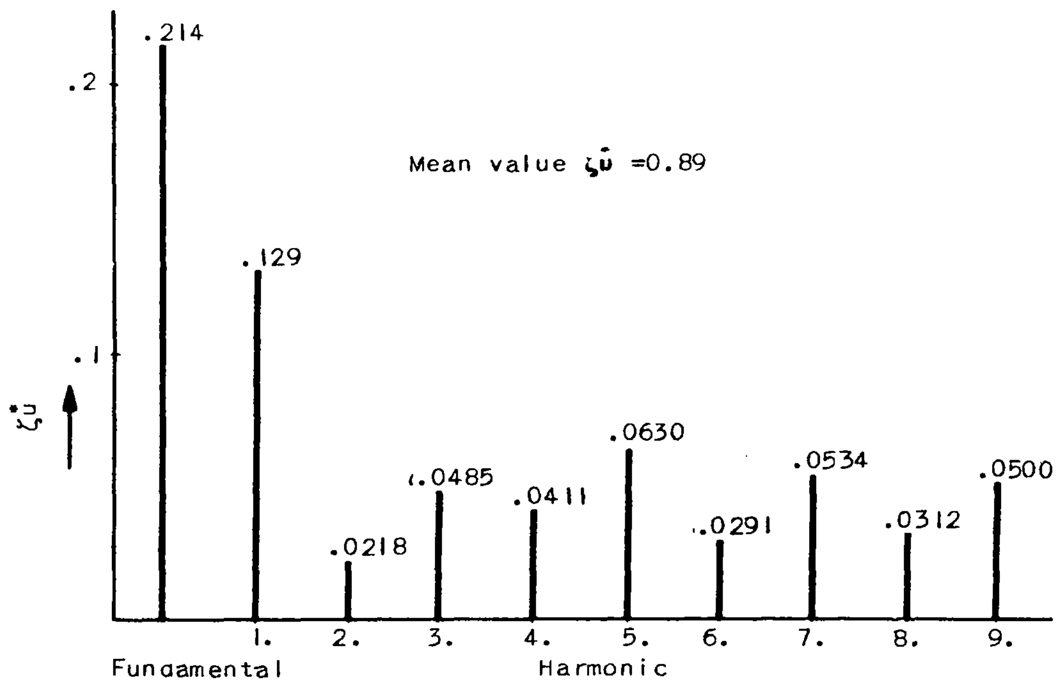


Figure 5. - Harmonic analysis of rotational force coefficient (double lattice investigation).